Final Report
for
May 15, 1998 through May 21, 2001

Optimization and testing of Electrically Conductive spacecraft Coatings
Contract Number NAS8-40557

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1.0 INTRODUCTION

This is the Final report discussing the work done for the Space Environmental Effects (SEE) program in the Materials and Processes Laboratory, on electrically conductive thermal control coatings. These thermal control coatings are being developed to have several orders of magnitude lower electrical resistivity than most available thermal control coatings. Most current coatings tend to have resistivities from 10^{11} to 10^{13} ohms/sq.

Historically, spacecraft have had thermal control surfaces composed of dielectric materials composed of either polymers (paints and metallized films) or glasses (ceramic paints and optical solar reflectors). Very seldom has the thermal control surface of a spacecraft been a metal where the surface would be intrinsically electrically conductive. The poor thermal optical properties of most metals have stopped them being used as a thermal control surface. Metals low infrared emittance (generally considered poor for thermal control surfaces) and/or solar absorptance, have resulted in the use of various dielectric coatings or films being applied over the substrate materials in order to obtain the required optical properties.

During the 1970's, surface charging of spacecraft began to become a concern to the industry. In the late 1980's and early 1990's, this problem became significant as electronic systems became more sensitive to electrical anomalies and spacecraft surfaces were damaged through electrical arc discharges. Electrical discharges can be generated from spacecraft interaction with the electrically neutral environment. Interaction between spacecraft and environment can cause charge segregation. This has resulted in charged spacecraft surfaces in both GEO and LEO orbits, depending on the external biasing of the spacecraft. Indium tin oxide has been used to alleviate surface electrical resistivity problems for many applications. However, this and similar materials are typically deposited as thin films and tend to be susceptible to damage from cracking or delamination when deposited onto thin and/or flexible substrates. The damage to the electrically conductive thin film can cause a loss of electrical conductivity and an increase in surface charging. The coatings developed and tested under this program will yield coatings that effectively deal with the problem of surface charging of spacecraft.

On May 15, 1998, a contract was awarded to AZ Technology by NASA through the SEE program and monitored through the Marshall Space Flight Center for the development of electrically conductive spacecraft coatings. The purpose of this effort was to develop both white and black spacecraft coatings which have electrical resistivity values below currently available thermal control coatings and which maintain their optical and electrical properties when exposed to the space environment. Also, the coatings are designed to be deposited onto large complex surfaces with a minimal difficulty or environmental impact. The development of these low-resistivity, thick film coatings will be a significant step forward in materials and spacecraft technology.

1.1 Background

An issue that still maintains a prominent spacecraft problem is the build-up of surface charge resulting from interaction of the spacecraft with its orbital environment of charged particle radiation or space plasma. The charging of a spacecraft surface can further be intensified

as spacecraft increase in size, with increased power requirements payload sensitivity to electrical noise and discharges are increasng for such items as instruments and sensors. Other factors like the electrical biasing of a spacecraft power generation system can also contribute to this problem. Space Station will be the largest and highest-powered spacecraft put into orbit. It is anticipated the structure will be driven to approximately 140V negative to the ambient plasma and will use one or more plasma contactors to maintain near neutral surface charge.

1.1.1 Surface Charging

Basically spacecraft surface charging results from several different kinds of charging phenomena and how they interact with the various surfaces of the spacecraft. The different kinds of charging phenomena are typically the following: 1) electrons from space plasma, 2) photoelectrons from spacecraft surfaces, 3) ions from space plasma, 4) secondary electrons from a surface, typically generated by initial electron impacts, and 5) secondary electrons from a surface, resulting from initial ion impacts. Charge transfer typically occurs in one of the following ways: 1) from the surrounding environment to the spacecraft, 2) from the spacecraft to the surrounding environment, or 3) between different spacecraft surfaces. The interaction of these factors is highly complex and can not be adequately addressed within the confines of this document. Though the interactions of spacecraft and the space environment together cause much of the charging problems, one can not neglect the interaction that can occur between different materials on or in the spacecraft as well as electronic and electrical grounding circuits which also contribute to the formation of surface charging. Hence even with our current level of understanding schemes for controlling surface charge build up, there continues a need to develop and certify greater varieties and ranges of electrically conductive thermal control coatings for flight hardware use.

Spacecraft surface charging is believed to be responsible for the loss or damage of a number of satellites and the production of anomalous instrument data. With the development of spacecraft like the Tethered Satellite (TS) and others carrying instrument packages far more sensitive than previous systems, the problem of conducting electrons has become even more difficult to master. Tethered Satellite's function was to study the space plasma environment surrounding the earth. To perform this task, the exterior surface coating not only was required to act as an effective thermal control surface, but also as a good electrical conductor. Because of this electrical conductivity requirement, current state of the art thermal control coatings were evaluated based not only on their thermal optical properties but even more importantly, on the coating's intrinsic electrical conductivity. Through extensive testing and a few serendipitous events, it was determined that the coating originally selected and applied to TS was ineffective because of poor vacuum electrical conductivity. Marshall Space Flight Center developed an effective and successful coating (RM-400) to meet the needs of the short duration TS mission. However, what is actually needed is a long-term, spce stable coatings for a variety of space and potentially aircraft applications.

Currently, only a few thermal control coatings have been produced that effectively dissipate surface charge build-up for specific applications or conditions. Little is known and understood of these with the possible exception of a few low (0.16 to 0.30) solar absorptance coatings produced by Space Craft Incorporated (SCI) and Jet Propulsion Laboratory (JPL) which have been extensively tested and investigated. Of the high (0.85 to 0.98) solar absorptance

coatings, most are based on polymer binders and or graphite and carbon pigments which are not appropriate for all uses or orbits. Therefore the problem of damage from electrical arcing or discharge still cause many problems for the spacecraft industry. The coatings developed under AZ Technology's SBIR are completely inorganic, and are comprised of soluble glasses and ceramic pigments potentially making them useful for most if not all orbits.

Each coating has its strong areas of performance. However, these coatings were developed to be electrically conductive and, as can be seen, the ceramic coating has poor performance in this category which is the most critical for it's intended mission. The RM-400 performs well in the areas of conductivity and thermal emittance but falls short in the category of solar absorptance (α_S), as a radiator coating, with a value of 0.49. Typically for radiator coatings a solar absorptance value of 0.25 or less is required.

Extensive research has taken place over the last few years to develop a variety of spacecraft coatings with the unique property of being able to conduct surface charge to a substrate or grounding system. The ability to conduct surface charge to a safe point, while maintaining optical properties and performance, is highly advantageous in maintaining operational space based systems. Without this mechanism the surface of a spacecraft can accumulate charge to the point that a catastrophic electrical breakdown can occur, resulting in damage to or failure of the spacecraft. Ultimately, use of this type of coating will help mitigate many of the concerns that NASA and the space industry still have for their space based systems. When these spacecraft coatings are found to meet stability needs, they can be used to control electrical charge build up and possibly conduct sufficient electrons for power generation from the space plasma, as was demonstrated with the tethered satellite. The unique coatings that we studied fall into two specific categories: 1) broadband absorber (black α_s= 0.94 to 0.97), and 2) selective absorber (white α_s=0.16 to 0.30). These coatings have controllable solar absorptance and electrical surface resistivity values over the designated ranges. These coatings were developed under an SBIR program which focused on the development of such constituents and coatings.

Our project focused on simulated space environmental effects testing with the intent of using this data to help optimize the stability and initial properties of these coatings. It was originally planned to expose candidate coatings to a new test that consists of exposing the candidate coatings (independently) to an environment of low energy charged particles (generally 10Kev electrons) and or UV with in-vacu electrical resistivity measurement. Then, if possible, expose independent, but of the same batch, to a combined environment of VUV, UV, protons, and electrons with in-vacu optical solar absorptance measurements. Through the utilization of such testing, our understanding of these coatings' space environmental stability will provide sufficient data to determine the coatings stability. Then if sufficiently stable, the tests would provide data needed for their acceptance by the aerospace community and their potential use on current and future space programs.

1.2 Purpose

The purpose of this research program was to test and try to optimize the electrically conductive thermal control coatings developed under a previous SBIR so that they could be used on spacecraft. The development and production of these types of coatings will be very useful for

the management of electrical charge that can accumulate on the surface of a spacecraft. Also, the developed coatings could be used for current collection, storage, and conduction in environments where metals would not be effective because of poor thermal-optical properties or material reaction with the environment.

1.3 Program Objectives

- Determine suitable reference coatings with significant ground testing and history and if possible flight data;
- Determine effect on coatings when exposed to the environment of the combined radiation effects chamber (VUV, UV, p+, e^-,and vacuum) with in vacuum optical measurements;
- Determine effect on coatings when exposed to the environment of the low energy effects (UV, e^-,and vacuum) with in-vacuum electrical measurements;
- Determine from SEE data if test coating needs to be modified to meet stability requirements;
- Develop a plan for optimizing test coatings (if needed), carry out plan and test coatings;
- Scale-up material volumes to be capable of effectively meeting industry needs for at least one white and black coating with the following requirements:

  – Initial properties

White Coating	Black Coating
– $\alpha_S \leq 0.30$	– $\alpha_S \geq 0.85$
– $\varepsilon_T \geq 0.85$	– $\varepsilon_T \geq 0.85$

  – Resistivity tailorable between 10^2 to 10^9 ohm/sq.

  – Contamination potential

    > Collectable Volatile Condensable Materials CVCM < 0.1%

  – Environmental stability when exposed to the space environment for one year

    > $\alpha_S \leq 0.10$

    > Change in resistivity $\leq 1x10^2$

  – Mass loss ≤0.5% when exposed to an AO fluence of $1x10^{20}$ atoms

2.0 RESEARCH AND EVALUATIONS

This Final report for Contract NAS8-40557 and describes the work for the period May 15, 1998 through December 15, 2000. Inclusive, is design, procurement, assembly, debugging, and procedural and methodology maturation, of a completely new space environment testing chamber. The program also included synthesis, formulation, and deposition of semiconductor spacecraft thermal control coatings, on custom substrates and subsequent testing.

2.1 Test chamber

This test chamber was designed by the Marshall Space Flight Center, to test and evaluate electrical conductor or semiconductor materials in a simulated space environment. It's purpose is to record what effect different forms of energy (radiation) have on external spacecraft materials performance, function and survivability (stability or lack of change) over time or radiation dose. As is shown and discussed in detail in the following paragraphs a custom designed vacuum chamber was fitted with both an electron flood gun and a thousand watt near ultra-violet (NUV) radiation source. These radiation sources can be used simultaneously or individually as needed to understand a particular phenomenon or material effect.

Table 1 provides the electronic components used to operate and acquire data from this unique space simulation test chamber. Use of dual radiation sources allowed NASA and AZ Technology investigators to evaluate the effects of two typical but very different energy sources naturally occurring in space. Invacu electrical measurements during space simulation irradiation testing should provide insight into possible different degradation mechanisms and how they effect the new generation of semiconductor thermal control coatings.

Table 1. Conductivity Research Equipment

EQUIPMENT	MANUFACTURER	DESCRIPTION
Electron Source	Kimball Physics	Model EFG-9 Electron Flood Gun Beam Energy: 1Kev to 50Kev Beam Current: 10^{-9}A to 10^{-4}A
Electrostatic Voltmeter:	Trek Model 344	Voltage measurement range: 0 to ± 2 kV DC Measurement accuracy: ± 0.1% of full scale Probe-to-surface separation: 1 ±2mm Resolution: 1 Volt with a sampling rate of 2.5 samples per second
Current Measuring Devices		
	EG&G Ortec Model 439	Digital Current Integrator
	Keithley Model 480	Picoammeter
	Keithley Model 619	Electrometer
	EG&G Ortec Model 996	Timer & Counter
	EG&G Ortec Model 439	Digital Current Integrator
Data Acquisition Equipment		
		Pentium 233 Industrial Standard Computer System
	Labview	Labview Software Version 5.0
		NI-6025E PCI Multifunction I/O Card
		NI-6025E PCI Multifunction I/O Card
		NI-4060 PCI Digital Multimeter Card
		SC-2062 Electromechanical relay digital output board
		SC-2050 Cable Adapter Assembly
		CB-50LP Connector Block
	Analog Devices	5B Series Analog Signal Conditioning Assembly

Figure 1 illustrates how the electronic components listed in Table 1 are linked together and provide measurement feedback to the data acquisition system for storage and display. Other major areas were system integration, software development and control, and data acquisition systems. This test chamber system was designed and built by NASA MSFC ED-31 personell.

Because this is a unique system with many unknowns there has been a variety of redesigns, changes in methodologies and procedures to obtain meaningful data.

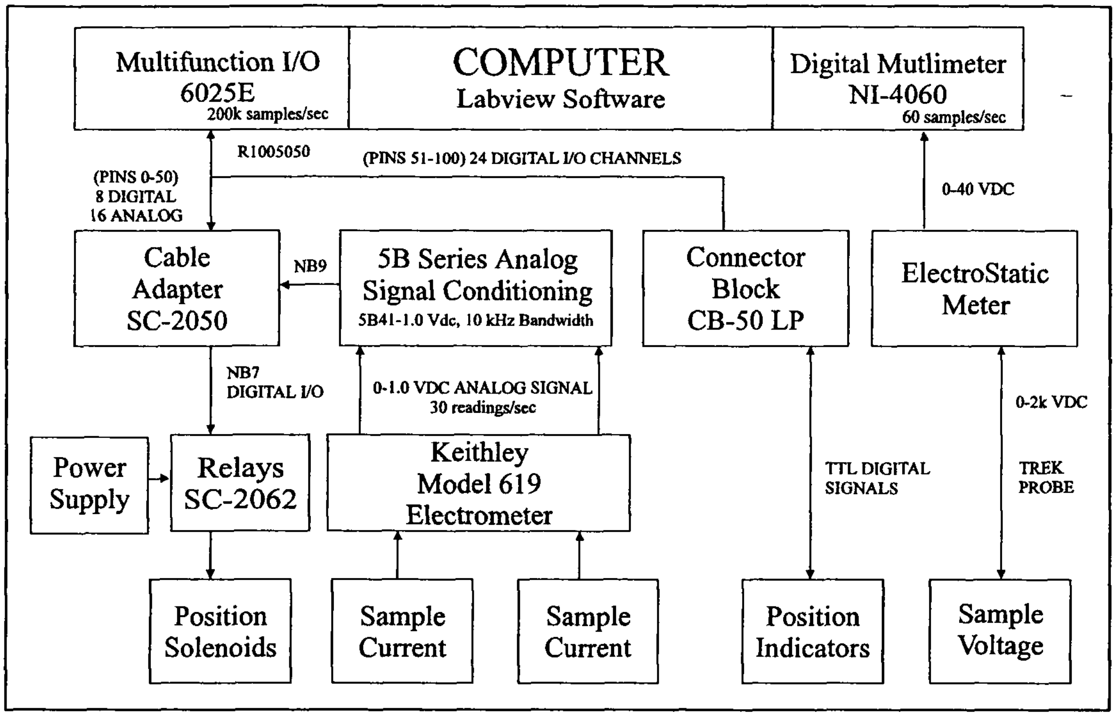

Figure 1. Conductivity Test System Control & Data Acquisition

Figure 2 shows the general configuration layout of the test chamber. The electron flood gun and the NUV source are each off set by 5.5 degrees in the horizontal (Z) axis from normal and are normal to the to the samples in the vertical (Y) axis. This minimizes the offset angle to the sample, while providing sufficient separation.

NUV source was equipped with a dichroic infrared (IR) energy filtering system to minimize sample heating. Both sources were located at a distance from the samples that resulted in coverage of test samples and detectors with a uniform beam. A UV grade quartz window was used to allow the externally mounted NUV source to pass into the vacuum test chamber. The entire system was pumped down using a vacuum turbo pump. Samples were exchanged through a ten inch diameter quick access door airlock combines with a viewport.

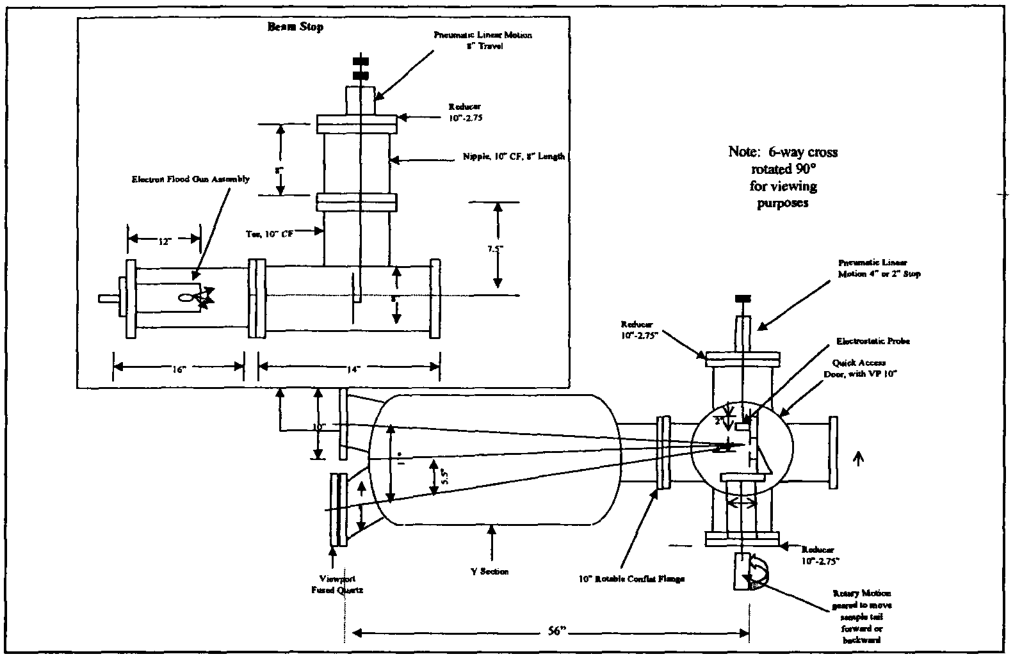

Figure 2. Conductivity Test System

2.2 Sample Coupon Configuration

The sample coupon configuration is described in the following paragraphs. The sample coupon was made of 6061-T6 aluminum alloy. The front edge was rounded to a radius of 0.12 inches to eliminate electrical charging edge effects. The sample coupon was made up of an outer ring and the inner ring or disc. The inner disc was 0.75 inches in diameter with a 0.001inch gap between it and the outer ring. This gap was filled with Kapton film used as an insulator between the inner and outer discs of the sample. The back of the sample was insulated with a 0.06 inch thick Teflon disc fastened to the aluminum sample coupon with Teflon screws.

In the center on the sample backside, an electrical contact site was machined in the sample. This contact site was located in the center of the inner disc. This was used to monitor the current flow through the test coating on the front surface of the sample coupon.

Initially sample coupons were coated across and over the Kapton separator located between the inner and outer sections of the sample coupon. This was changed when it was found to result in a charge collecting area larger than expected. As a result of these findings sample coupons were coated before assembly to ensure that the gap between the inner and outer coupon sections was not coated. This change in coupon coating configuration helped to ensure that a charge collecting area was confined to the inner disc of a coated sample coupon.

2.3 Conductivity Test Procedure:

Before starting a test the electrostatic probe is calibrated using the following procedure. A reference sample is positioned above the samples to be tested and this is done to keep the reference sample protected from the radiation source(s). This eliminates possible change in the reference sample that such exposure could cause. Then the reference sample is connected to a 0

to 2kV-power supply and the electrostatic probe is placed in front of the reference sample and measurements taken. Electrostatic probe readings must display the same voltage as the power supply. This verifies that the electrostatic probe is functioning properly prior to starting a run with test samples.

For the exposure of test samples to the electron beam, faraday cups are mounted near the samples to produce a current proportional to that of the electron beam current. The Digital Current Integrator measures this coulomb charge and produces a digitized output proportional to the number of incident electrons. The Counter/Timer and the internal counter of the Multifunction I/O board record this output. Sample surface to ground current is measured by the picoammeters. Digitized output from these picoammeters are signal conditioned by the Analog Devices 5B modules and are recorded and plot displayed on a monitor as a function of electron counts by the computer. For each electron count measured by the computer it will sample ten current readings and the average are recorded and displayed. Once the established number of electron counts is reached, (typically 1000) a relay is energized to automatically control and close the electron beam shutter. The current discharge of the test sample can then be monitored.

To measure the test sample surface voltage the following sequence is used. A position indicator verifies the beam stop is down before a relay energizes to move the electrostatic probe to the desired sample position. A Trek 344 Voltmeter performs a non-contacting surface voltage measurement. This surface voltage is sampled, recorded, and plotted as a function of a given length of time. Then the probe is repositioned to the reference/calibration position for the next test.

3.0 ELECTRICALLY CONDUCTIVE CERAMIC PIGMENTS

Previous studies at AZ Technology identified, and completed initial evaluation on a number of inorganic pigments. These materials have lower solar absorptance values than those identified in previous research at AZ Technology. These compounds had metal atoms that were specifically chosen because of their known or theoretical potential to produce low absorptance metal oxides in the UV through the NIR from previous research. Therefore AZ Technology took the approach of producing oxides and/or alloying known high reflectance substances to other metals (starting as organo-metals) or metal oxides. In so doing AZ Technology could potentially solve or decrease the impact of several problem areas that reduce the usefulness of thermal control coatings. The first is decreasing the solar absorptance of the TC coating to be more efficient in rejecting solar energy. Second is stabilizing the chemical structure against ion or free radical formation from solar radiation, hence decreasing degradation of these materials. Three is providing surface charge buildup protection through the formation of a semi-conductive pigment or additive.

2.1 <u>Evaluation Coating Additives and Binders</u>

New coating constituents, such as binder additives potassium hexafluorosilicate and potassium perchlorate can be used to aid in the stabilization of a thermal control coating. Potassium hexafluorosilicate could be used as a means to impede the loss of oxygen from the primary pigment. This is hypothesized to being possible because of the dense tightly bound electron cloud structure that resided around this compound. We intend to investigate, the

possibility that the use of such a compound will tend to inhibit the depletion of oxygen from the pigment that is used in a thermal control (TC) coating. Because of the dense electron cloud of this compound, it may help or at least impede an ionized oxygen atom from diffusing out of the coating matrix by electron donation or simple charge repulsion.

Another approach is the use of a perchlorate compound, specifically potassium perchlorate and ammonium perchlorate. The purpose of using this type of compound as an additive in a thermal control coating, is to act as a supplemental source of oxygen, since the for most white TC coatings degrade through the loss of oxygen. We had no success introducing this material directly into a silicate binder. When the perchlorate came into contact with the silicate solution, precipitation of the silicate occurred and forms a solid. The precipitated silicate is rendered useless as a binder in this state.

A few other alternatives arepossible. One is to purposely mix the perchlorate with silicate while mixing at high speed, thus potentially producing a homogenous solid that then could be ground and added to a coating. Second is to blend the perchlorate with the pigment and determine if the pigment will act as a buffer slowing down or stopping the rapid solidification that now occurs.

A new type of binder material has also been undergoing some initial evaluation. It is currently a proprietary binder material that is supplied to AZ Technology to determine it's utility for space applications. The reason it was evaluated during thisstudy or program is its transparency, as shown in Figure 3 versus that of a potassium silicate as shown in Figure 4. This new material has promise, because of the facts that not only does it have very good transmittance, more importantly, it under goes significant shrinkage during the curing process. The shrinkage character of this binder material is very important because of several aspects.

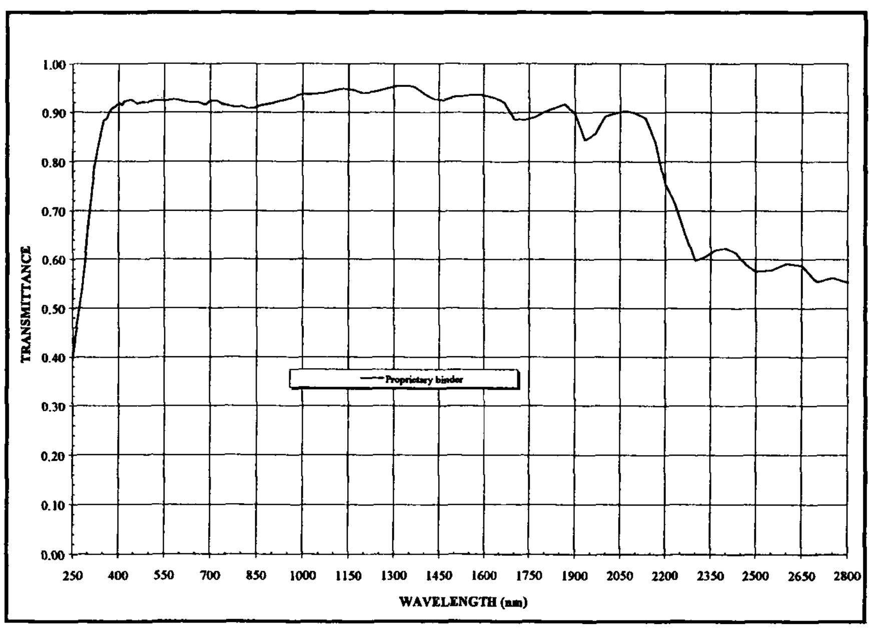

Figure 3. Transmittance of Proprietary Binder Through The Solar Spectrum

First, the binder does not degrade mechanical bonding to an aluminum substrate as a consequence of shrinking. Two, this binder does not seem to loose physical adhesion, nor does it appear to crack or fracture during this process, even as a neat film compound. Third, a binder that shrinks as part of an electrically conductive coating curing process without fracturing, forces the conductive particles to be pulled together. Binder shrinkage without crack propagation should result in a more efficient conductive coating.

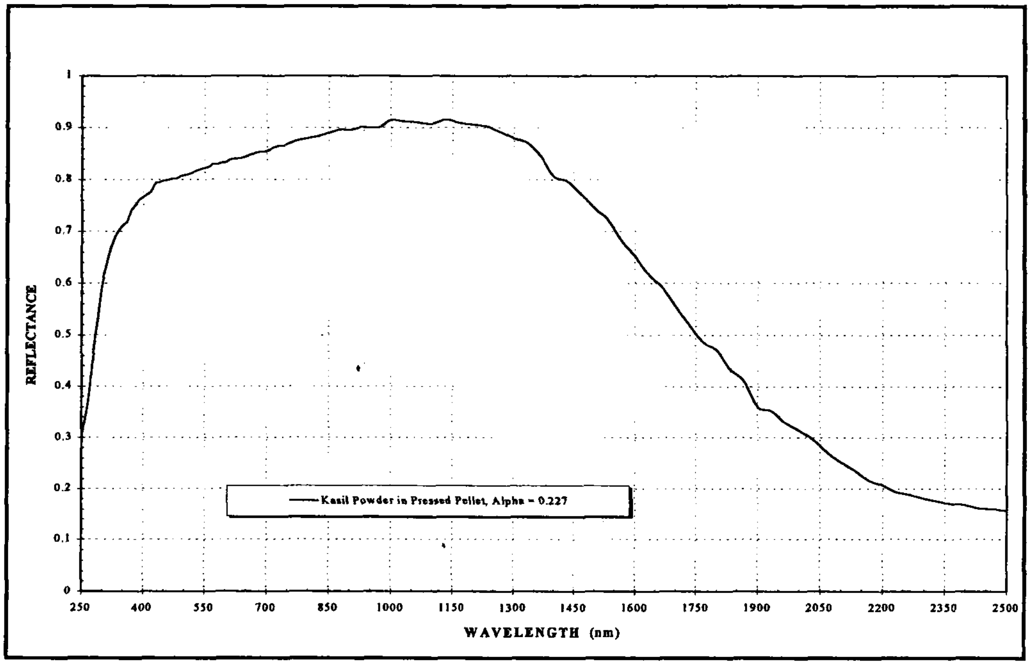

Figure 4. Solar Absorptance of Potassium Silicate Binder

To demonstrate the potential of this binder AZ Technology currently has produced a coating using this potential binder and calcined zinc oxide, shown in Figure 5. With a pigment loading less than that used for AZ-93 and a similar cured coating thickness of 4.5 mils, we achieved a comparable solar absorptance value of about 0.155. For a first attempt these results were quite promising.

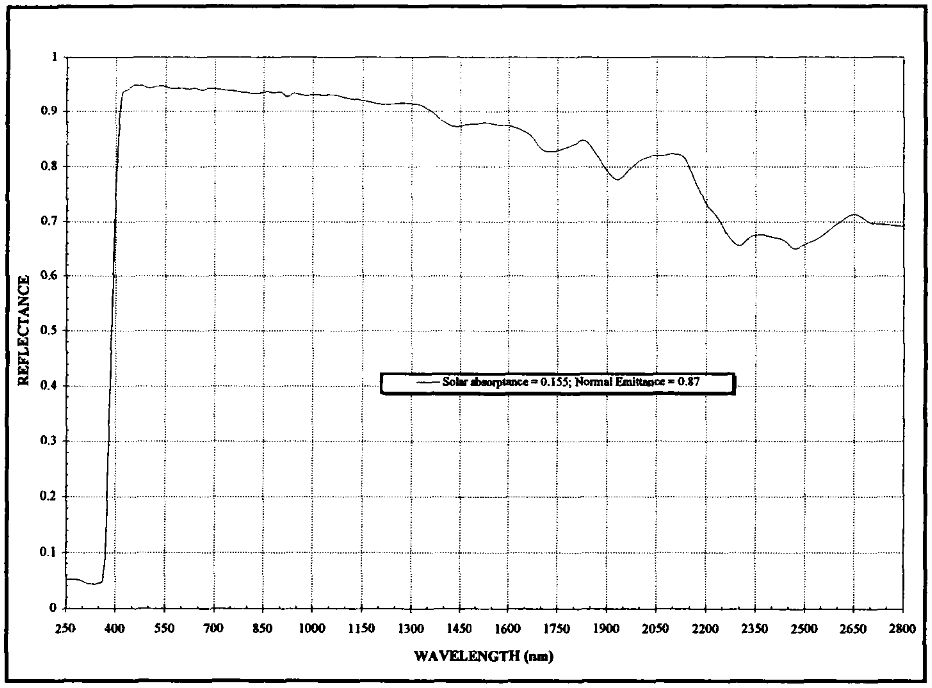

Figure 5. Solar absorptance Zinc Oxide pigmented Boeing binder

2.2 Optimization of Electrically Conductive Ceramic Pigments

During this program AZ Technology lsowas engaged in the development of whisker type material that has good conductivity.

The synthesis and production of a whisker like semiconductor material provideS a much better mean free electrical pathway for electrons to flow than the relatively poor one produced by the typical particle to particle contact. We did discover that in the SBIR that very white and electrically conductive whiskers could be produced. But the yield was very low and the whiskers were almost impossible to separate and collect from the nonconductive residue left behind after the reaction was finished.

The approach that we used is to utilize what we refer to as supports. The term supports as we use it, means that the semiconductor precursors are deposited on to a whisker (short fiber). The supports that we are using are commercially available by products of the composite industry and are available composed of a variety of materials. The types of materials available, range from carbon to zirconium oxide. Processing starts by producing a solution that will react to form the semiconductor. In our current process the solution of semiconductor precursors overcoat the supporting whisker with the material. The overcoated support material is then dried and heat treated to produce the final semiconductor having acceptable optical properties e.g. white, black or transparent.

Although this processing appears easy, and has been successful so far, we still need to investigate the various coating parameters and detailed techniques need to be worked out.

However, at the present time our knowledge base in this process is limited. Four support materials given in Table 2 were investigated.

Table 2. Support Materials

MATERIAL	RATIONAL FOR USE	COLOR	DIMENSIONS LENGTH BY DIAMETER
Carbon / Graphite	O_2 Reactive leaves hollow core, and is low mass impact on coating	gray	3-8 mm x 8-12 μ.
Quartz/Silica	Transparent if mixed with many binders, little effect on solar absorptance	Clear to white	10-14 mm x 20-30 μ
Zirconium oxide	Good reflectance throughout solar spectrum. May help to enhance α_s of some coatings	white	1 mm or less x 8-12 μ.
Silicon carbide	Good support material for black coatings, good documentation in ceramic applications	Gray to black	3-8 mm x 8-12 μ.

The primary challenge is to determine which technique is going to be better to use with supports, and to determine coating material by mass or volume percent. Because we are dealing with whisker materials that have a wide range of densities, determining a good ratio of whiskers to solution is very difficult since we have a wide range of parameters to satisfy. Sum of which are solution concentration, viscosity, coating technique, and drying. Even with all of these variables to consider this seems to be a viable approach as the results of a trial run shows in Figure 6.

As is seen in Figure 6, using the previously discussed whisker coating method formation of the desired type of material can be achieved. These whiskers were produced using a carbon support and a fine particle dispersion of tin oxide. The resultant product after heat treating is a white whisker that should provide a good electrical pathway with little effect on thee optical properties of the thermal control coatings. The measured resistance was 10^3 to 10^4 $\Omega/\square$ in air using only a multimeter and straight probes. It is not likely that we will be able to obtain a more accurate resistance value using the Hewlett-Packard electrical resistance cell, because of the volume of material required, until these whiskers can be incorporated into a coating.

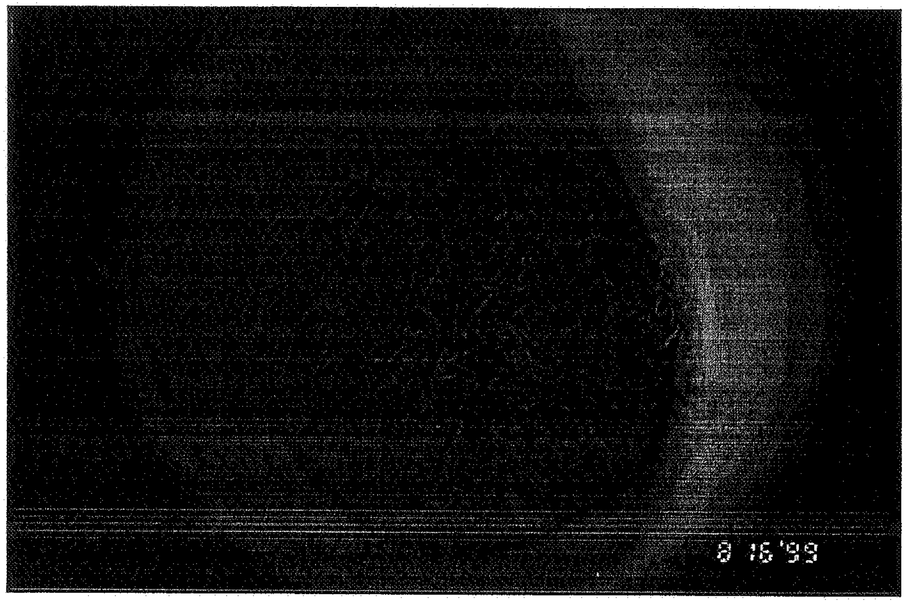

Figure 6. Synthesized Electrically Conductive Whickers

4.0 EVALUATION OF THERMAL CONTROL COATING STANDARDS

Three thermal control coatings were manufactured and deposited by AZ Technology onto a special type of coupon designed by NASA MSFC ED-31 personal. These thermal control coatings were chosen to use as system test and checkout standards for the in vacuum conductivity test system. These three coatings were chosen for the following reasons. One is a known dielectric (zinc titanate); the second is zinc oxide, (a natural moderately good semiconductor); and the third is an AZ Technology engineered good (low electrical resistance) semiconductor developed as part of a previous NASA SBIR program.

The rational for using this approach was to use well known thermal control coatings with established flight and ground testing characterization and heritage. The primary consideration for use of established thermal control coatings is the documented optical degradation rates of these coatings resulting from exposure to documented levels of near UV or electron exposure. The solar absorptance property was chosen since, it is the coatings feature that has historically been of greatest importance to the survivability of most space flight hardware. In addition, a few people have hypothesized for many years that at least to some degree, as these coatings degrade (increase in solar absorptance) the electrical conductivity of the coating increases by the formation of surface mobile electrons. Through the use of this new test chamber we determined if the standards chosen do or do not exhibit the hypothesized effect of increasing electrical conductivity vs. exposure dose. Also, and more importantly how does this exposure to near UV and/or electron energy effect the electrical conductivity and solar absorptance of the new semiconductor thermal control coatings. Even though solar absorptance can not be measured directly with this new test system, it still can be measured relatively at the end of an exposure by back filling the chamber with nitrogen. This measurement is done by removing the samples and measuring immediately with an UV-NIR reflectometer. Another approach is to place another sample of the sample coating and batch into the combined radiation effects chamber at MSFC;

expose the sample to the same dose of near UV and/or electrons as was used in the electrical conductivity test chamber, and then correlate the results.

5.0 CONCLUSION

Very preliminary test data gathered to date seems to follow an expected logical trend. The zinc titanate (dielectric) coating accumulated a surface charge in the order of approximately 2500 to 2700 volts. However, this coating did crack and delaminate in some places when exposed to the chamber vacuum and therefore these approximate values may have large errors associated with them. Failure of the coating is thought to result from insufficient cure time. The test sample was cured for only three days instead of the normal fourteen days. The zinc oxide designated AZ-93 (a natural moderately good semiconductor) coating accumulated a surface charge in the order of approximately 175 to 225 volts. Previous space environmental effects testing by this author, as a research team member at IITRI found that this type of coating would accumulate a maximum charge of about 500 volts if the sample was properly grounded. These values were made using a crude faraday cup system. When these measurements were made the test samples were also exposed to a somewhat different radiation environment composed of 17 Kev neutral protons and a near UV source. During the tests at IITRI sample exposure was typically a minimum of about two weeks of continuous exposure. Finally an AZ Technology engineered semiconductor coating designated ECB-1 would not accumulate a surface charge during the initial testing. Further testing at a dose of a thousand counts using the same AZ-93 and the ECB-1 samples produced consistent and reproducible data. Further experiments were carried out at 3000 counts using the AZ-93 and ECB-1. At this dose some voltage spiking was recorded and through visual observation small electrical arcs were detected on the AZ-93 sample. This phenomenon was not observed when the ECB-1 sample was exposed.

